Global Distribution of Freshwater Wetlands for use in STOCHEM

Hadley Centre technical note 32

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Introduction

Wetlands are an important ecosystem which must be considered for modelling of atmospheric chemistry and climate change, as they are a major source of methane. In pre-industrial times, wetlands were the largest single source of methane. The global mean radiative forcing due to atmospheric methane (at 2000 levels) is 0.48 W m^{-2}, or 20 % of the total radiative forcing due to all well-mixed greenhouse gases (IPCC, 2001). In a future scenario where wetland areas experience a warmer, wetter climate, it seems likely that the methane emissions will increase significantly. The distribution of wetlands over the globe is also important. First, the climate will strongly control methane production and emission. Wetlands in tropical regions will emit methane all year round, whereas wetlands at high northern latitudes will only produce methane during the warmer months; when the ground is frozen, no emissions can occur. In this report, "wetlands" will specifically mean freshwater wetlands which potentially emit methane. Salt marshes, for example, are not considered as they do not produce significant methane fluxes (Aselmann and Crutzen, 1989). The main types of wetlands are described below. Next, five sources of information on wetland distribution are listed, and the corresponding maps of each distribution (at the end of this report) are discussed briefly. The maps are compared, and wetland databases used in various modelling studies of global methane levels are given. Finally, a recommendation for STOCHEM is presented.

Types of Wetlands

There are many different types of wetlands, which may be conveniently grouped into six types (Aselmann and Crutzen, 1989), although other classifications are possible (for example, Matthews and Fung, 1987).

Bogs:
Bogs are peat-producing wetlands which exist in moist climates where organic material has accumulated for a long time. Water and nutrient input occurs entirely through precipitation. During peat formation, the ecosystem has moved upwards above the water table. Consequently, bogs are acidic and nutrient deficient.

Fens:
Fens are also peat producing wetlands, but receive nutrients from water flowing through the system. They are less acidic than bogs, and may even be mildly alkaline. Fens are more prolific than bogs owing to their better nutritional status. The largest area of fens are in boreal and tundra regions, including the areas of permafrost in the extreme north.

Swamps:
Swamps are forested wetlands on waterlogged or inundated soils, where little or no peat formation occurs.

Marshes:
Marshes are herbaceous mires with grasses, sedges or reeds. They may be permanent or seasonal, and are subject to gravitational water levels. The distinction between swamps and marshes is arbitrary if the vegetation cover is not stated.

Floodplains:
As their name implies, floodplains occur alongside rivers and lakes, and are periodically flooded. The vegetation cover is highly varied. Seasonally flooded savannahs in Africa and South America are the major wetland type in this category.

Shallow Lakes:
Open bodies of water of a few metres depth which may emit methane through the water column and into the atmosphere. This category is only considered for Europe, Africa and South America. In cool temperate and arctic regions they are included in one or more of bogs, fens and marshes.

There are currently five different wetland distributions from which methane emissions can be calculated. These are listed below. In the near future, wetland areas and locations will be available as a diagnostic from MOSES. Note that the process-based models of Cao et al. (1996) and Walter and Heimann (2000) use a pre-existing wetland distribution to calculate methane emissions; they do not produce a wetland distribution themselves.

Sources of Wetland Distributions

1. The original wetland and tundra databases (wetland_big and tundra_big) as used in STOCHEM.

2. The database of Matthews and Fung (1987) as used by Fung et al. (1991).

3. The database of Aselmann and Crutzen (1989).

4. The updated version of Aselmann and Crutzen's database, by Stillwell-Soller et al. (1995).

5. The ecosystem database of Olson et al. (1983).

A brief description of each dataset is given below. In all cases, the globe was divided into a regular grid, although the resolutions vary considerably. Maps showing the wetland distribution from the five datasets are given at the end of this report. The wetland distribution maps for databases (1) and (2) above were generated from emission files. In each case, any grid cell from which methane is emitted at any time of the year was flagged. For datasets (3) and (4), the percentage area of each cell on the grid which is wetland was available. Dataset (5) assigns one of approximately 50 different ecosystem types to each cell in the grid, of which 3 ecosystems are clearly identifiable as wetlands.

Figure 1. Original wetland and tundra emission database used in STOCHEM. Two data files are available giving an annual emission of methane per grid cell per year. Although the data are presented on a 5 x 5 degree grid, they appear to have been transferred from a coarser one. Any cell which emits methane has been marked.

Figure 2. The wetland methane emission database of Matthews and Fung (1987) was obtained from the GISS website (http://www.giss.nasa.gov/data/ch4fung). The dataset consisted of 12 methane emission files (one for each month) based on this wetland distribution which were used by Fung et al. (1991) in their modelling study of global methane emissions and atmospheric concentrations. The additional methane source from certain tundra regions used by Fung et al. (1991) was added to the original wetland database. The data are on a 1 x 1 degree grid. A cell which emitted methane at any time during the year was marked. The resulting map therefore shows the extent of the wetlands.

Figure 3. The original database of Aselmann and Crutzen (1989) consists of maps of various wetland types on a 5 x 2.5 degree grid. The maps give the percentage of the area of that grid cell which is covered by wetland type. A summary map giving the total wetland area in each grid cell is also given. This summary map is presented here.

Figure 4. An updated version of the Aselmann and Crutzen (1989) database by Stillwell-Soller et al. (1995), which focussed on wetlands in Alaska which were not identified in the original database. This database was obtained from the UCAR website (at location http://www.scd.ucar.edu/iag/lana). Stillwell-Soller et al. (1995) used a new map of Alaska which identified areas of bogs and fens, and also other data from field work and aerial photographs. No other part of the original database of Aselmann and Crutzen (1989) was modified. The data were then interpolated from the original grid used by Aselmann and Crutzen (1989) to a 1 x 1 degree grid. The map shows the percentage area of each grid cell which is covered by wetland.

Figure 5. The ecosystem database of Olson et al. (1983). A database of world ecosystems on a 0.5 x 0.5 degree grid of which 3 ecosystems were clearly defined as wetlands: mire (bogs), marsh and swamps. Grid cells marked as tundra were also included. All these cells are shown on the map.

Comparison of Wetland Distributions

The wetland distribution used in STOCHEM (figure 1) covers most of the globe, and so includes many areas which the other databases do not classify as wetland, particularly over much of Asia and Australia.

The wetland distributions of Matthews and Fung (1987) and Aselmann and Crutzen (1989) are similar (figures 2 and 4 respectively). Both databases show a concentration of wetlands in Scandinavia, Siberia and parts of Canada. The database of Aselmann and Crutzen (1989) shows more wetland in Amazonia than that of Matthews and Fung (1987); the situation is reversed in central Africa. Surprisingly, Aselmann and Crutzen (1989) do not identify any wetlands in Alaska, whereas Matthews and Fung (1987) show a significant amount. However, the updated version of the Aselmann and Crutzen database by Stillwell-Soller et al. (1995) addressed this problem. A comparison of Figures 3 and 4 shows significant wetland areas now exist in Alaska, which is in better agreement with the database of Matthews and Fung (1987), shown in figure 2.

The ecosystem database of Olson (1983), shown in figure 5, does not identify all wetland types. Many of the forested wetlands are not explicitly identified. Comparison of figure 5

with figures 2 and 4 shows a very different wetland distribution. It would appear that the Olson ecosystem database is not suitable for identifying all types of wetlands.

Wetland databases used in global modelling studies of methane levels

Reference	Wetland database used
Fung et al. (1991)	Matthews and Fung (1987)
Hein et al. (1997)	Matthews and Fung (1987)
Lelieveld et al. (1998)	Aselmann and Crutzen (1989)
Houweling et al. (1999)	Matthews and Fung (1987)
Houweling et al. (2000)	Aselmann and Crutzen (1989) + Walter and Heimann (2000)
STOCHEM	Various

Recommendations for STOCHEM

There are five different databases of wetland areas and distributions currently available which could be used for methane emission distribution and climate studies. Of these databases, only three actually identify different wetland types explicitly. These are the databases of Matthews and Fung (1987), Aselmann and Crutzen (1989) and Stillwell-Soller et al. (1995). The latter two are identical except over Alaska, where the missing wetlands in the database of Aselmann and Crutzen (1989) have been added by Stillwell-Soller et al. (1995). The databases of Matthews and Fung (1987) and Stillwell-Soller et al. (1995) have similar total wetland areas and overall distributions, although significant differences do occur in some areas. However, Aselmann and Crutzen (1989), and later Stillwell-Soller et al. (1995) used data specifically identifying wetlands to construct their databases, whereas Matthews and Fung (1987) used more indirect information (maps of soil types, vegetation and inundation). Aselmann and Crutzen (1989) also state that Matthews and Fung (1987) may have included salt marshes and other areas which are only occasionally flooded in their database. It is therefore recommended that the database of Stillwell-Soller et al. (1995) should be used to describe wetland distributions in STOCHEM. In the future, the wetland diagnostic from MOSES may be used, but is not available at the time of writing.

References

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Fig.1. STOCHEM Wetland Distribution Based on Emissions (wetland and tundra). Resolution: 5.0 x 5.0 degrees

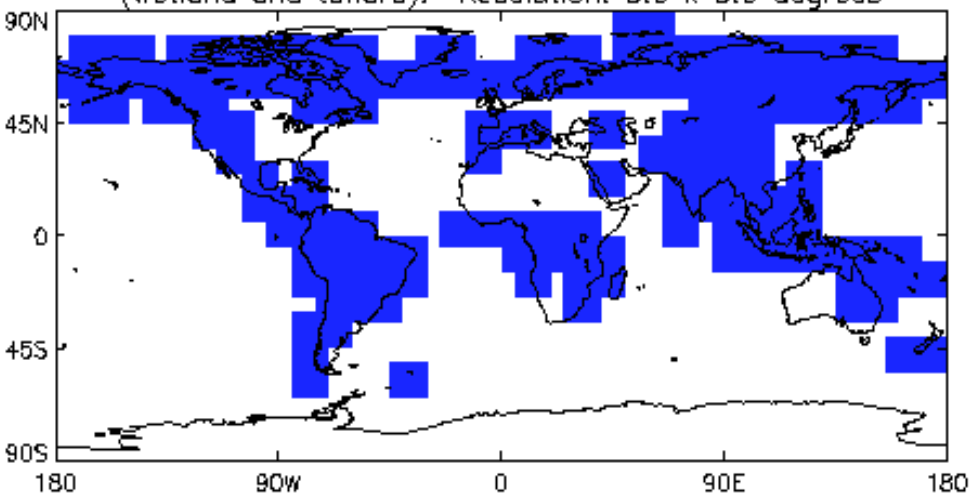

Fig.2. Matthews/Fung 1987 Wetland and Fung et al. (1991) Tundra Based on Emissions. Resolution: 1.0 x 1.0 degrees

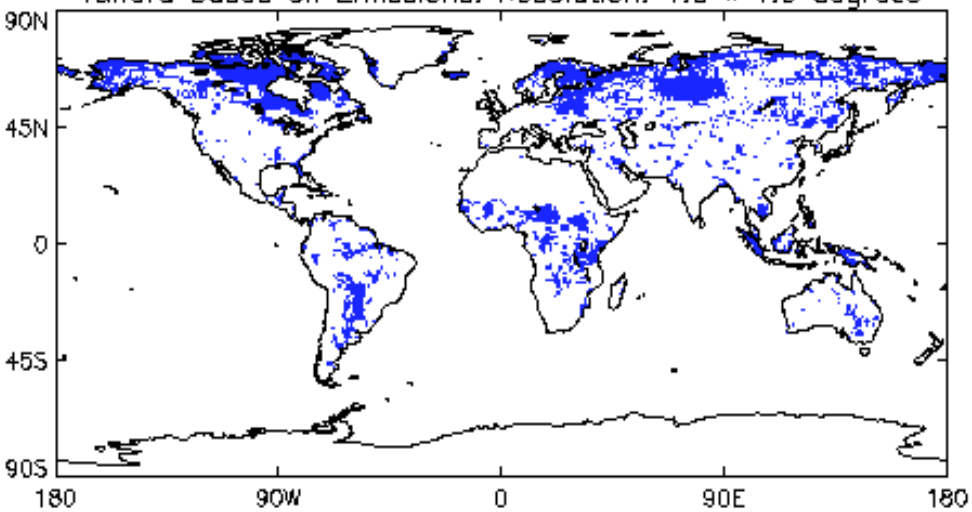

Fig.3. Aselmann/Crutzen 1989 Wetland Distribution
Resolution: 5.0 x 2.5 degrees

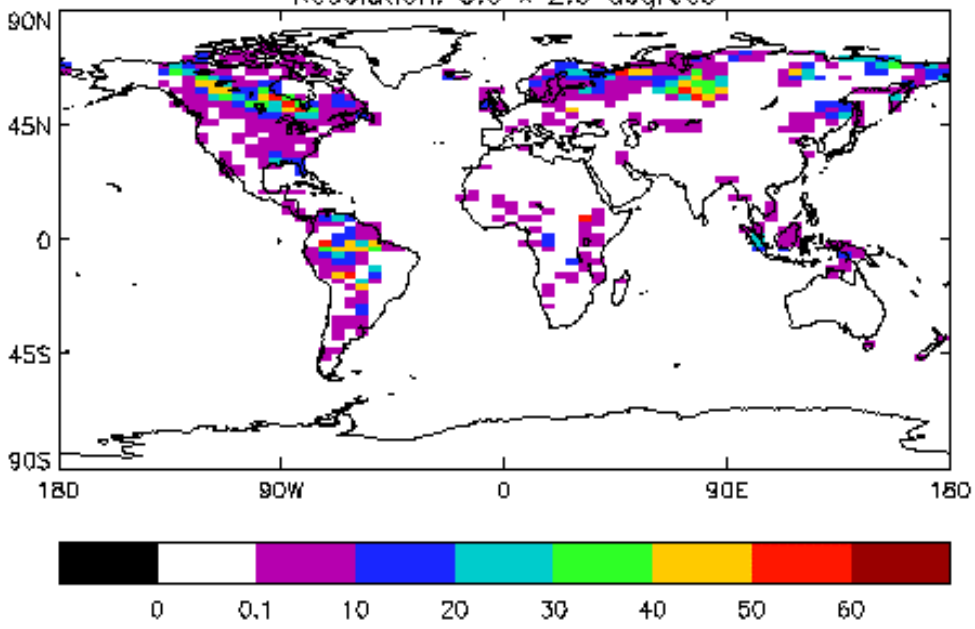

Fig.4. Stilwell-Soller et al. (1995) Wetland
Distribution. Resolution: 1.0 x 1.0 degrees

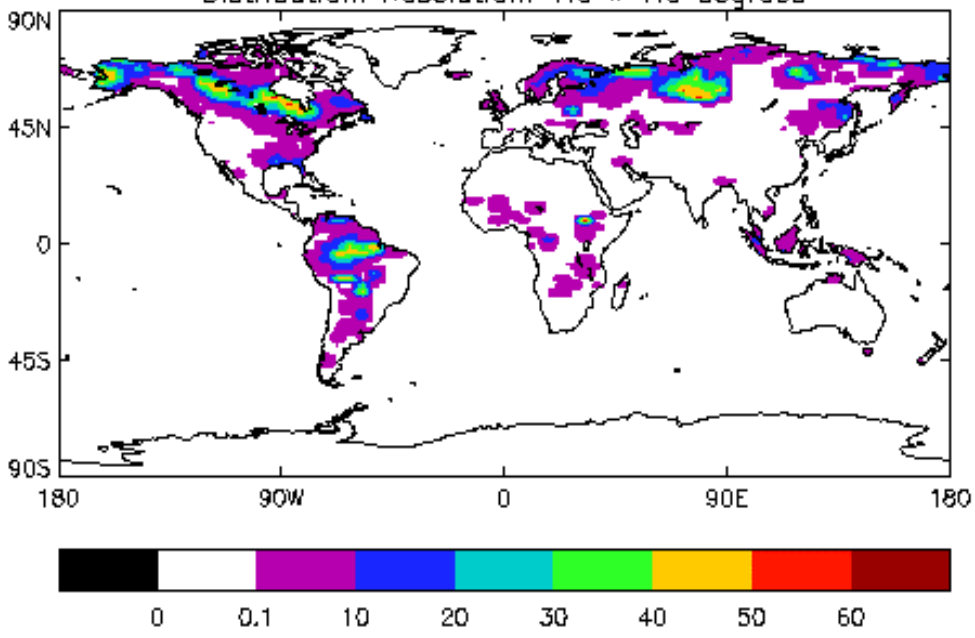
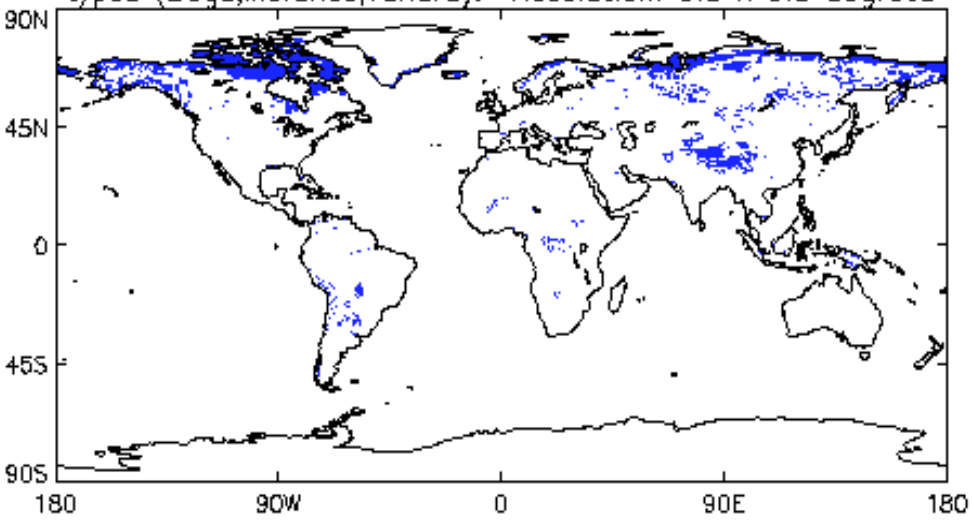
Fig.5. Olson 1982 Wetland Distribution Based on Ecosystem types (Bogs,Marshes,Tundra). Resolution: 0.5 x 0.5 degrees